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ALICJA SALAMON

SMALL-WORLD SOCIAL NETWORK VISUALISATIONS

Master of Science thesis

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ABSTRACT

ALICJA SALAMON: Small-world social network visualisations
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We live in a data driven age. Now, there is more data available than at any point in time before. However, the more data is made accessible, the more difficult it is to analyze it. Information visualisation is the art of representing data visually to help to deliver understanding of it.

This thesis studies visualisations of social network graphs. Its main objective is to research possible approaches to represent the users' social network on a mobile phone screen and allow them to traverse its graph. The design aims to support users with exploration of their social network and to enable them to discover unexpected information about its structure.

The work on the thesis consisted of a research and a design phase. Research was composed of a questionnaire about possible purposes of utilizing an access to a social network visualisation and participatory design sessions where participants took an active part in activities of body storming, card sorting and storyboarding.

Based on the gathered results, three visualisation approaches were proposed. The first one is based on a map view and focuses on showing the physical location of the users. In the second approach user traverses the graph by travelling from one point of view of the selected node to another. The last approach shows nodes grouped into six circles based on the length of a path needed to reach them.

The final outcome of a thesis demonstrates a possible answer to the addressed research questions and presents several appropriate ways of graphical representation for a social network graph that provides a captivating user experience and allows for exploration and discovery.

Design is an opportunity to continue telling the story,
not just to sum everything up.

- TATE LINDEN

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LIST OF ABBREVIATIONS AND SYMBOLS

HCI	Human-Computer Interaction
HCD	Human-Centered Design
NFC	Near Field Communication
UI	User Interface
UX	User Experience
WFD	Wi-Fi Direct

1. INTRODUCTION

According to the six degrees of separation phenomenon, any two randomly selected people are linked on average by a path of 6 connections [38]. This compelling fact provides an opportunity for a particular approach for social network data exploration. This thesis studies visualisations of small-world social networks according to the six degrees of separation theory. Its aim is to support users with exploration of their social network and to enable them to discover unexpected information about its structure.

This chapter describes the background for the thesis topic and the motivation behind it. Next, it explains the objectives of the research and chosen methodology. Finally, the thesis structure is presented in the end of the chapter.

1.1 Background and motivation

Visualisation of social networks has a rich history. The first visual representations of social relations emerged in 1930s in a form of hand-drawn sketches by Moreno who pictured a social structure as a graph of nodes and links [41]. The field then advanced with studies on bigger and bigger groups - researchers have been visualising datasets of users exchanging emails [15] or participating in online chats [43]. From 2000s social networking services started to emerge, capturing the relations between their users. Since then, enormous amount of data has been gathered about users and interactions between them [24].

With the growth of the visualised datasets, the need for more advanced visualisation techniques appeared. As a consequence of a complicated structure and large amount of nodes, it became difficult to visually represent the emerging patterns [24]. One of the most notable phenomena discovered about the structure of social networks, was that an average path between any two nodes in the graph is surprisingly short. The original work of Milgram proved that despite the size of the population, we live

in fact in a small world where any two randomly selected people are connected on average by only six links [38].

Users of current social networking services like Facebook and Twitter constitute a gigantic network that is a compelling structure for exploration. Researchers have been studying visualisation approaches that would highlight the small-world property of social networks graphs. In particular, research by Ingram describes 3D visualisation that utilizes the topological features to group nodes into clusters [28]. Similarly, Auber et. al. focus on interactive navigation between such clusters using a method based on semantic zooming [5].

With of all the research already conducted in the network visualisation field, a visualisation curated especially for end-user still may prove useful. This thesis aims to design a service with focus on data visualisation that would allow users to extract complex information about the structure of their friendship network and to comfortably traverse its graph. The motivation behind the thesis is to create a social network graph visualisation that delivers understanding of the structure of the user's social network and proposes ways of utilizing the access to it.

1.2 Research Objectives and Methodology

Popular social media services serve as a platform for building social relations with other people and for sharing information with them. However, these platforms have not been constructed with a goal of being a tool for convenient graph traversal and analysis. For that purpose a professional software for graph examination exists - it is however complex and predestined to be used by scientists.

The goal of the thesis is to discover possible approaches for a small-world social network visualisation that allows for exploration and discovery. The visualisation should make graph traversal straightforward for a user with no scientific background, simultaneously providing a captivating user experience. In particular, the research questions that the thesis addresses are:

- How to visualise a social network of a small-world structure?
  - What information should be made accessible to the users?
  - What kind of interaction with data should the visualisation support?

– For what purposes access to user's social network visualisation could be utilized?

The methodology used to achieve the final design is based on the Human-Centered Design framework. This approach was selected as its main objective is to provide a product that focuses on user effectiveness, efficiency and user satisfaction. The methodology includes the practices that facilitate gathering understanding of users, their tasks and their environments [12].

In HCD the needs and limitations of users are considered at each stage of the design process [1]. The work on the thesis consisted of research and design phases, both of which included user input. In the research phase a questionnaire was distributed to test the feasibility of the concept. Next, participatory design sessions were conducted to actively involve users in the design process. In the sessions participants took part in activities based on body storming, card sorting and storyboarding.

As Human-Centered Design focuses heavily on ensuring that the outcome meets user needs, gathering user feedback is essential part of the process. Collected information is then used in the next stages of the work to create a product providing good user experience.

1.3 Structure of the thesis

Chapters 2 and 3 introduce the relevant theoretical background. In particular, chapter 2 describes social networks and explains the structure and characteristics of small-world networks. It presents both the pioneer research and the current social media status. Chapter 3 focuses on information visualisation and gives the most attention to the existing network visualisation techniques. It demonstrates common representations of a network structure and possible interaction approaches. The chapter concludes with an overview on information visualisation evaluation methods.

The utilized research methods are described in Chapter 4. Chapter demonstrates the research schedule and detailed information about all conducted studies and their setup. Chapter 5 covers the obtained results, their thorough analysis and drawn conclusions.

Chapter 6 illustrates the designs created throughout the course of the work on the thesis. It depicts the process from the concept design to the final outcome in a form of freeze-frames from created animations.

Lastly, Chapter 7 summarizes the key findings and discusses the success and importance of the outcomes. It summarizes the answers to the posed research questions. Chapter 8 concludes with discussion and future work recommendations.

2. SOCIAL NETWORKS

A social network describes a social structure determined by personal relationships. This chapter describes the history of the research on social networks, basics of their analysis as well as the structure and parameters specific for small-world networks. It presents examples of social networks and compares the structure of existing global social networking services.

2.1 Research development

Research in the area of social networks originates from 1890s studies of Emile Durkheim and Ferdinand Tonnies who examined social groups and patterns of relationships that emerge within them [18]. Major developments in the field begun in the 1930s when Jacob Moreno developed the first sociograms out of the data he gathered from documenting social interactions in small groups, mostly classrooms (Fig 2.1) [41].

One of the most groundbreaking experimental studies about the structure of a social network was conducted by Stanley Milgram in 1967 [38]. Milgram examined the number of intermediate acquaintances necessary to connect two randomly selected US citizens. For the experiment Milgram selected a diverse group of people and asked them to pass a prepared folder to an acquaintance of theirs who is most likely to know the target person. In the study 44 out of 160 chains were completed, starting from Nebraska with the target person in Cambridge. The path length varied from 2 to 10, with a median at 5, proving that the number of links needed to connect two people is in fact quite small. In consequence, Milgram coined the term "small-world phenomenon".

The structure of social networks remains a popular research topic, with many analogous experiments being conducted, for instance using e-mail chains [13]. With the enormous amount of data gathered from popular networking sites, it has been proven

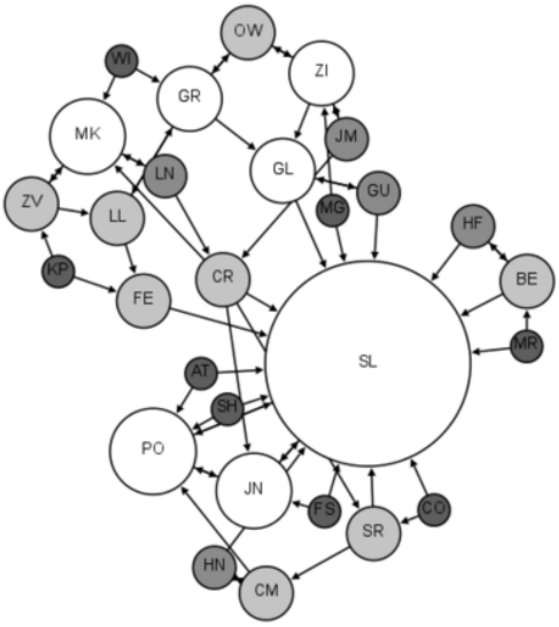


Figure 2.1 *Example of a sociogram.*

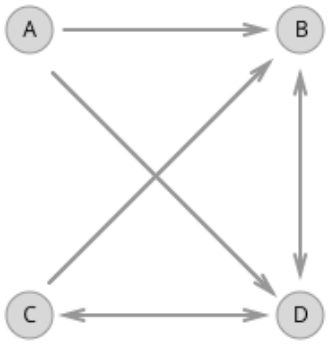
that the social networks have in fact a small-world structure with surprisingly small number of intermediate links between their users.

2.2 Social network analysis

Classic social network analysis studies a structure of a network built on a set of people being nodes of the graph, and a relationship between them being the graph's edges. The analysis allows for extracting meaningful information, for instance: detecting unexpected patterns, identifying a role a person plays in the network or following information propagation.

2.2.1 Nodes and edges

A graph consists of a set of nodes and a set of edges that connect certain pairs of nodes. Graphs are commonly represented in a form of an adjacency matrix. Graphical representation consists of points to represent users and lines to represent relations between them. These kinds of graphs are sometimes called sociograms (Fig. 3.2) [41].



	A	B	C	D
A	x	1	0	1
B	0	x	0	1
C	0	1	x	1
D	0	1	1	x

Figure 2.2 *Popular graph presentations: graphical on the left, adjacency matrix on the right*

A single node represents one person in the network. It can be labeled with various information about the individual like name, age or interests. A degree of a node is the number of edges connected to that node. An edge is a direct link from one node to another. It represents a relation between two users. An edge can be undirected, meaning that the connection is symmetrical, or directed if the direction is important. In directed graphs edges are usually represented by arrows. An edge can have a value assigned to describe the strength of a tie. It can be binary when it represents presence or absence of a tie, signed (represents a negative tie, a positive tie, or no tie) or valued with the number assigned [9].

Centrality of a node is a parameter that describes how "central" a node is in the network, what can be used to estimate its importance. There are many different measures of centrality, the most common are degree centrality (based on the degree of the node), closeness centrality (based on a node's distance to every other node) and betweenness centrality (based on the number of the paths that go through the node) [23].

Nodes in the network can have different roles, for instance role of a hub or a bridge. A bridge is a node that provides the only link between two separate clusters. Bridges have a critical role in information propagation through the network. Hubs refer to the most connected nodes in the network, their role is to keep the network together [20].

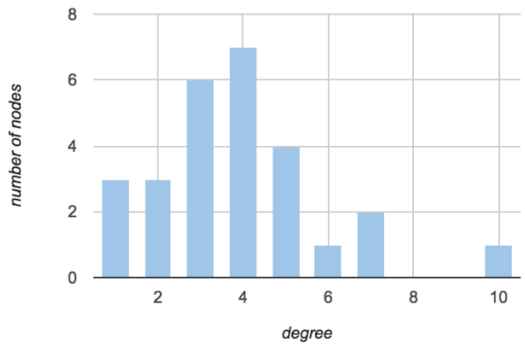


Figure 2.3 *Example degree distribution graph*

2.2.2 Network parameters

A social network can be described by a number of parameters. The most basic are the number of nodes and edges describing the network's size. Directly from these two variables the average node degree is determined.

The degree distribution describes the degree for all the nodes in the network and shows the number of nodes per each degree. The degree distribution is most commonly represented in a form of a bar chart (Fig. 2.3) Density of the network is calculated as a ratio between the number of existing edges to the number of all the edges that could possibly exist. This parameter describes how densely connected a network is [23].

Another parameter is an average path length calculated as the average of all the shortest path lengths for all possible pairs of nodes in the network. A network's diameter is the largest of those distances [23].

Cliques are the network's components in which all nodes in a group are connected to one another. Network's cliquishness is determined by clustering coefficient [23]. Clustering coefficient is calculated as a fraction of pairs of node's neighbors that are connected to each other. In practice high cliquishness designates groups of people closely bound together.

The degree to which individuals bond with people similar to themselves is measured by homophily. Similarity can be defined by many aspects like location, age, occupation or interests [37].

Figure 2.4 *Regular, small-world and random networks*

2.3 Small world networks

A small-world phenomenon is the idea that in the global network of people we are all connected by short chains of acquaintances. Often it is referred to as the "six degrees of separation" principle that claims that any two people can be connected by no more than six links [22]. Small-world networks are characterised by number of properties.

Small-world network structure is characterized by a short average path length and high clusterization. It does not resemble neither a random nor a regular graph (Fig. 2.4). An example of a famous small-world network is a network of film actors where the average path between two actors was calculated to be 3.65. Studies conducted on global social networking services prove that social networks have the small-world networks properties [57].

Additionally, studies have shown that almost all of the people in social networks are connected and number of non-connected nodes is negligible. Social networks are scale-free, meaning that they follow a power law: most of the users have small number of connections and only a few users have numerous connections (Fig. 2.5). In-degree and out-degree are correlated: users who link often to others, are also more often linked to [40, 2].

2.4 Global Social Media

Many studies have been conducted on the biggest global social networking services like Facebook, Twitter or Google+. The results confirm that social networks have indeed a small-world structure [30, 55, 34].

In Twitter, network connections are asymmetrical - a user follows a number of users

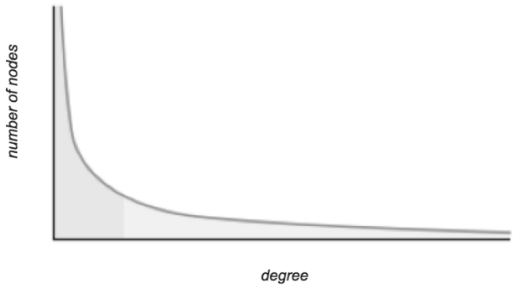


Figure 2.5 *Power law distribution*

but it does not mean they automatically follow him back. 67.6% of users are not followed by their followings. In 2009 there were only 40 users with more than a million followers, what shows how the network fits power-law distribution. The average path length (4.12) is extraordinarily small for a network of this size [30].

Facebook graph is almost fully connected - 99.91% of users belong to the same large component. The average number of friends in Facebook is 190, the median is 99. The average path length is 4.7 - 99.6% of Facebook users are connected by six or less connections [55].

In Google+ users can add other users to their circles like 'family', 'close friends' or 'acquaintances'. User chooses to which circles he shares his content. Path length is higher than in other social networks [34]. A detailed comparison between the presented social media services is presented in the Table 2.1.

Table 2.1 *Social networking services comparison*

Network	**number of users**	**average degree**	**average path length**	**diameter**
Twitter	332 million	29	4.1	18
Facebook	1.59 billion	190	4.7	41
Google+	418 million	16	5.9	19

2.5 Summary

Study of social networks is an inherently interdisciplinary academic field that has been studied in detail for over a century and continues to be researched to this day. One of the most significant empirical studies in the field was undertaken by

Stanley Milgram who studied the number of intermediate acquaintances necessary to connect any two randomly selected people. Milgram's research coined the term 'small-world phenomenon'.

Studies of the most popular networking services confirm that social networks exhibit the characteristics of small-world networks meaning short average path length and high clusterization coefficient. This causes their structure to be between a regular and a random graph.

We in fact live in a small world where it is possible to reach any person by a relatively short path of connections. This fascinating phenomenon is inspiring both in fields of science and pop culture. It opens countless possibilities for exploring the society we live in and for utilizing the access to the information in many surprising ways.

3. DATA VISUALISATION

This chapter describes the field of information visualisation, provides examples and presents techniques and guidelines for creating successful visualisations. Special attention is given to graph visualisation and small-world networks in particular. Finally, the problem of human factors in information visualisation is discussed and available methods are presented.

3.1 Overview

Computing and the Internet have transformed the way of creating, collecting and retrieving information. As the volume of available data is growing, people are getting exposed to more information than can be easily processed. Thus, the science of information visualisation is becoming increasingly more important. It allows users to explore and analyze data to understand described issues and to utilize gathered knowledge.

3.1.1 Visualisation types

Information visualisation studies the techniques of communicating information with graphical forms with an aim to deliver understanding of a certain issue [29]. Data visualization is its subfield concerned especially with graphical presentations of large-scale collection of numerical data. Its goal is to allow users to explore and manipulate it. Lastly, scientific visualization puts an emphasis on realistic renderings of complex scientific data in fields like architecture, meteorology and medicine. Its main purpose is to help scientist with analysis and comprehension of complex phenomena [17].

Overall, all of those disciplines have a common goal. They aim to communicate information to the users clearly and efficiently, conveying a certain message.

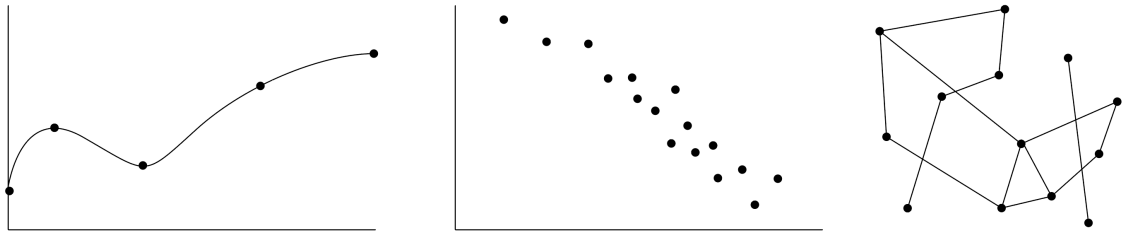


Figure 3.1 *line chart, scatter plot, graph*

3.1.2 Data types and common techniques

Reflecting on a data type in the initial stages of design is crucial as it allows to select the most suitable representation. Many tools offer an easy way to visualise the most common data types in graphical forms like line charts, scatter plots or graphs (Fig. 3.1). A useful taxonomy proposed by Shneiderman divides most often found datasets into several categories [49]:

- 1-dimensional data that includes basic linear data like alphabetical lists
- 2-dimensional data like maps or flat layouts (for example for newspapers)
- 3-dimensional data representing objects like molecules or human body
- Multi-dimensional - more complex data sets with more that 3 attributes per item
- Temporal data that describes a process and includes its timeline
- Trees are hierarchical structures like family trees
- Network data - structure of nodes and relationships between pairs of them

Static visualisations are the most straightforward, but they are often limited as they present only one perspective on the given information. Introducing interactivity enables users to explore the data themselves [42]. The most common user actions like overview, zooming, filtering and obtaining details-on-demand should be considered in a dynamic visualisation to encourage engagement with the data [49].

Data visualisation is not by any means limited to those data- and interaction types. There are limitless ways of presenting data and designers choose the method that serve their purpose best. Often visualisation are made interactive, to add another

dimension to the complexity of graphic representation. In the field of data visualisation there are countless techniques to deliver both understanding and delight.

3.1.3 Guidelines and principles

There are several universal rules that designers follow to guarantee the success of designed information visualisations. One of the key mantras describing the structure of interactions is:

> "First overview, then zoom and filtering, finally details on demand" [49]

First, user should be able to see an overview of the entire collection of data, then select and examine in more detail the items of his interest, filtering out uninteresting parts at the same time. Lastly, detailed information about selected items should be provided on user's demand.

Tufte created a set guidelines about the visuals of successful information representations that became a common set of practices. They aid information visualization designers in creating information representations that are both usable and beautiful. Tufte's rules focus on presenting the complexity of the data in a simplistic design [54].

- Graphical Excellence - Visualisation should aim to be clear, precise and efficient. The focus is on usability, rather than on creating decorative representations. The visualisations should be useful for the users and support them in exploration of presented information.
- Visual Integrity - Visualisation should never distort the data and allow for its incorrect interpretation. For instance, scales should be properly proportionate and legends should be unambiguous. Overall, visualisation should not distort the data and allow for its misinterpretation.
- Maximizing the Data-Ink Ratio - This rule advocates reducing visual clutter created by elements like borders, backgrounds or gradients that distract users from the information itself. Designer should use minimal number of elements that suffice to present data unambiguously. All parts of the visualisation that do not add to the understanding or are redundant should be omitted.

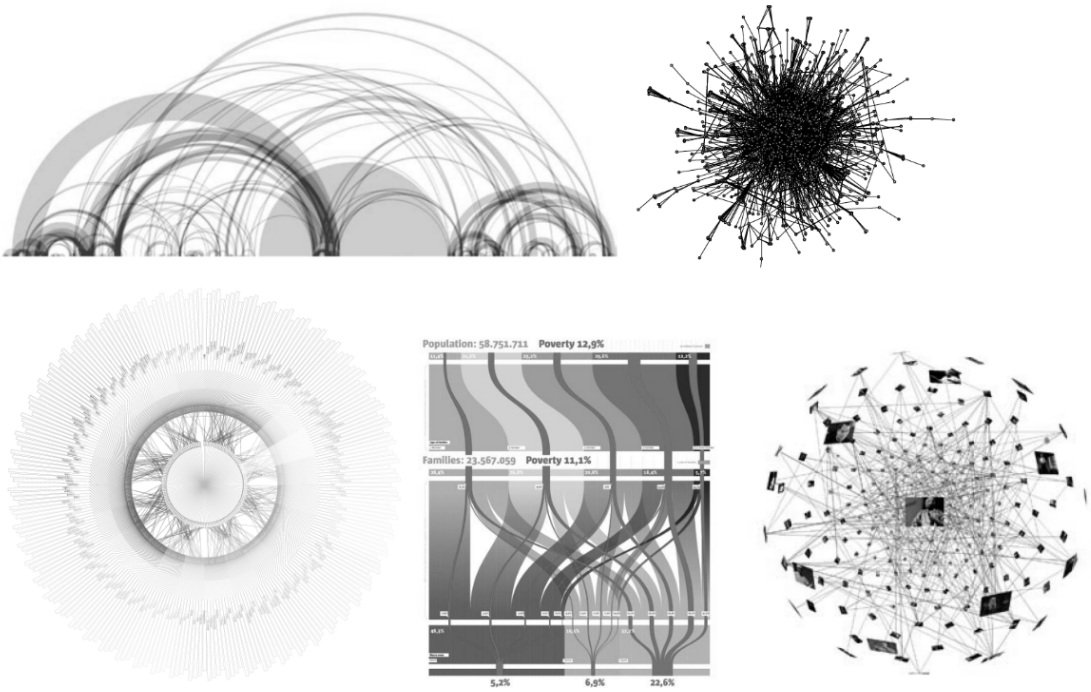


Figure 3.2 *arc diagram, circled globe, flowchart, centralized burst, radial convergence [35]*

Another guideline is to consider visual metaphors that can be used to structure the information and aid the user in comprehension of the data presented in a visualization [59]. Metaphors can make abstract and complex information understandable by indicating a relationship between presented ideas. For instance, categories can be highlighted by a metaphor of visual containment and hierarchy can be indicated by part-whole or up-down schemas [46]. Grouping of the elements can be illustrated by visual properties like similarity, proximity and closure that help organize separate visual elements into comprehensible structures [51, 44].

3.2 Network visualisation design techniques

Many real-world datasets can be naturally represented as networks or trees. Any set of items with relations between pairs of them can be visualised as a graph. Examples include family trees, public transportation maps or a social network structure. Network visualisations present graphs to the user and simultaneously provide a way of interacting with the data so that users can obtain meaningful information and discover the structure and dependencies in presented data.

Network visualisation is not trivial. The key issue is usually the size of the graph. If it is large, it cannot be presented to the user as a whole because of screen size limitation. Additionally, a big amount of data might be too difficult to comprehend. Instead, user can be shown an overview that will present an overall structure or a detail view that will let him to focus on a particular subset of data.

There are countless techniques for network visualisation. The ones for relatively small datasets often focus on distributing nodes so that the graph is planar (no edges are crossing). For larger datasets the focus shifts towards showing the structure of the graph and displaying interesting phenomena. Lima's taxonomy [35] of current practices in network visualisation includes techniques like arc diagram, circled globe, flowchart, centralized burst, radial convergence illustrated in the Figure 3.2.

In large graphs it is impossible to present all the details at once. Hence, there is a need for navigation that enables users to traverse the graph in order to obtain more detailed information. There are several classic approaches for graph navigation [25].

- "Zoom and pan" is a traditional technique that allows for changing the scale in which graph is drawn and moving between the areas. There are two kinds of zooming: geometric zooming that simply provides a bigger version of the content and semantic zooming that allows for the information content to change with a zoom factor and adjust the amount of details.
- In a "focus and context" technique contextual information when zoomed in is not lost. Popular approach that allows to see both the details and the context is a fisheye distortion. It enlarges a selected part and simultaneously reduces the remaining areas (Fig. 3.3).
- Incremental exploration is used when a graph is too large to be displayed as a whole. Only a part of it is presented to the user in the beginning, he can gradually explore it and reveal the hidden parts on demand.

In general, in the network data visualisation there are several key issues that need to analyzed before attempting the design work [36]. First is the node positioning that says where the particular vertices of the graph will be located. Nodes of larger graphs are usually distributed by an algorithm of choice. Additionally, node attributes like shape are color are determined. Next, the representation of the edges is chosen, for example they can be drawn as lines or arrows. In many cases edges can have

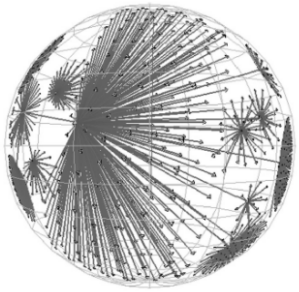


Figure 3.3 *Fish eye distortion [25]*

assigned value that can be illustrated by thickness of lines, colors or numerical labels. Finally, the design might include interactive elements that enable users to change views or obtain additional details. Interactions are important especially in large graphs, where the information should to be portioned and presented to the user in chunks.

3.2.1 Small-world network visualisation

Small-world networks structure demonstrates characteristics of both random and regular networks, and therefore it usually cannot be visualized with traditional methods. It has special properties that should be taken into account when visualising them - a short average path length and a big clusterisation index.

Studies have been conducted to discover useful method for small-world network visualisation. One of the methods proven successful in the 2004 study of Ham is based on creating a hierarchy of special nodes that are themselves clusters of regular nodes. Researchers paired it with a fisheye focus technique navigation for the best results [56]. Another study notices that the clusters of the network have itself a structure of a small world. Consequently, the graph can be decomposed into a network of smaller structures what can help with the visualisation process and enable semantic zooming (Fig. 3.4) [5].

3.3 Human Factors in Information Visualization

Human way of perceiving and interacting with graphics strongly affects the understanding of the displayed data. Cognitive psychology studies the factors that affect

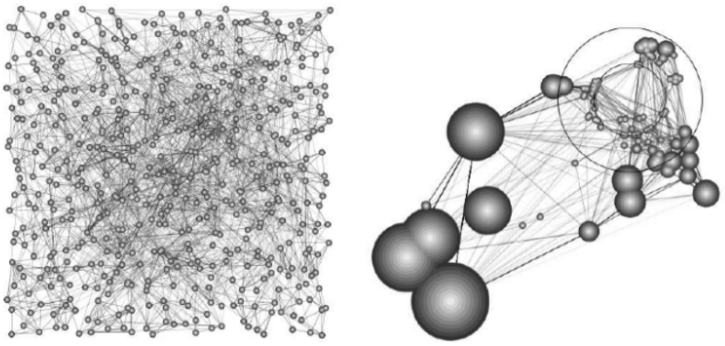


Figure 3.4 *Small-world network before and after clusterisation [28]*

how users process the information from the initial perception through information selecting and decision making [19].

One of the human factors that should be considered in information visualisation is a short-term memory. The amount of information that can be processed in a given moment is limited to only couple of memory units. Miller talks about 7 ± 2 chunks that can be simultaneously processed [39], however later study by Cowan indicated that the capacity of memory might be limited to even 4 ± 1 units [11]. Information visualisation designers should therefore consider limits of working memory and avoid high memory load, for example by using familiar metaphors.

Another factor that affects information processing is user attention, so ability to selectively focus on a property of information. Usually a person cannot actively concentrate on several things at a time. For that reason it is important to exclude irrelevant information [4].

Common practices in Human-Technology Interaction field, like immediate feedback or reducing the memory load, can significantly improve users' perception [53]. Information visualisations should be evaluated to ensure that they meet all functional requirements, are effective, efficient and useful [36]. There are two possible approaches for information visualisation evaluation: analytics methods conducted by experts - like heuristic evaluation or cognitive walk-through - and empirical methods that collect insights from actual users.

The expert methods are rarely taken into use as there is no established set of heuris-

tics for visualisation. The empirical methods are utilized more often. They can be divided into quantitative studies that gather numerical data to verify hypotheses about the accuracy, time etc. and qualitative studies that evaluate usefulness from a user point of view based on their insights [36]. The methods used to evaluate a visualisation may consist of a combination of a quantitative study like a controlled experiment and a qualitative study like user observation or a focus group. Well planned and executed evaluations can identify potential problems with the visualisation and direct designers towards creating a visualisation more useful for their recipients.

3.4 Summary

Data visualization is both an art and a science. It aims not only to communicate the information, but also stimulates user engagement and attention. It allows for exploration and discovery limited only by human imagination and creativity.

There are established guidelines and common practices that aid designers in creating effective and useful visualisations. At the same time, for big datasets the task is not straightforward. As in these kinds of visualisations there is a need for navigation, they most often become interactive. Many professional tools for scientific data analysis emerged, but they are mostly targeted for scientific use. That leaves a gap for new visualisation techniques that provide information also to non-professionals.

Considering human factors in data visualisation field is extremely valuable. Including users in all stages of design work enables designers to create a product tailored for its audience. In the era of information overflow it is becoming increasingly more important. User should be able to understand the visual representation and be able gain insights from it.

4. RESEARCH METHODS

This chapter describes the research methods chosen to explore the topic of social network visualisation and to gather users' input on the presented concepts. The chapter includes a description of the selected methods and explains how they help to achieve the objectives of the research. The aim of the conducted studies was to gather information regarding possible purposes of utilizing an access to social network visualisation and users' expectations of such.

The research was divided into two separate studies, the first being an Internet questionnaire spread globally, the second - a set of studies with small groups of recruited participants. The research took in total 3 months, from March 2016 to May 2016 and the analysis of the results proceeded until the end of June 2016.

This chapter describes both of the applied methods. First, it covers a self-spreading questionnaire study, and then the participatory design sessions activities. Both studies are described in detail, the chapter outlines the main objectives, the study setup and the applied procedures.

4.1 Self-spreading questionnaire

4.1.1 Study objectives

The first study addressed two main objectives. First, the respondents answers were gathered to analyze their views on the possible ways of utilizing an access to a social network visualisation tool. The second objective was to validate the overall feasibility of the researched idea and to test if users are willing to spread a message across their network. The study examined readiness to create chains of friends to distribute information and measured the speed of the process.

4.1.2 Procedure

The first study was an online questionnaire composed of three parts. First, users were introduced to the topic by a short video, then answered an open ended question "What would you like to know about the network of your friends?". In the last part, each respondent was prompted to resend the link to couple of his friends. This type of a trust-based recruitment among friends of friends is a framework that allows to identify a large number of trustworthy participants who provide meaningful contribution [3].

The answers and the process of sharing were tracked with an embedded script. The answers were grouped by the value of a token unique per the position in the chain of respondents. Additionally, the timestamp of the answer and location of the participant were logged for further analysis.

4.1.3 Study arrangement

The study was launched with five initial participants chosen for the study. Each of them, without an earlier notice, was sent a personalized message with a link to the questionnaire. They were kindly asked for a favor of answering and spreading the questionnaire and, if possible, prompting their friends to spread it further. Questionnaire design is attached in the appendix A.

Participants were chosen based on their nationalities, place of residence and relation with the author. None of the participants knew each other, they were stationing in 4 different cities and coming from 5 different countries. The selection was made carefully to ensure the best chances of covering a broad range of eventual respondents. The study concluded with 70 responses gathered, meaning that 65 of them were obtained by participants spreading the questionnaire themselves.

4.2 Participatory design

After the survey was closed and responses collected and analyzed, next study was arranged to refine the findings and broaden the understanding of the user needs regarding social network visualisations.

4.2.1 Study objectives

The second part of the research utilized the participatory design methodology. This approach aims to actively involve end users in the design process to ensure that the outcome meets their needs [50]. The study had several objectives. First, it aimed to validate the data collected from the previously conducted questionnaire and verify what are the most desired uses of a social network visualisation tool. Another purpose of the study was to gather data on users' perceptions of such a visualisation tool, desired interactions and information it should provide.

4.2.2 Procedure

Each session was designed to include 3-6 users and comprised three separate activities. The combination of various exercises helped to keep participants engaged while addressing different study goals. Workshops with users encompassed activities of telling, making and enacting, as recommended by Sanders et al. in their framework for conducting Participatory Design sessions [47].

Body storming
The first activity of the study was based on a body storming method, where participants are asked to act as if the studied tool already existed and imagine they are interacting with it [45, 48]. During this exercise users were told to act like they have just installed the application that allows for mapping the structure of their friendship network. Participants were handled a piece of paper, pen and stickers of different sizes representing friends in their network. Firstly, users were asked to add their friends to their network representation by shaking friend's hand followed by placing a sticker on the piece of paper. Later, users were asked to find a connection to people participating in the session who they did not know beforehand. During the activity users were encouraged to comment and discuss the structure of their network and the way it is growing.

The purpose of the exercise was to engage users, introduce them to the topic of social network visualisation and gather their impressions of a tool that would allow for browsing and exploring such a graph. Additionally, the visualisations created throughout the process were gathered and analyzed later in terms of their layout.

Card sorting
The next activity in the session was inspired by a card sorting method. Participants

were given a set of cards representing various scenarios of utilising a social network visualisation tool. The cards were designed based upon the results from the questionnaire distributed in the first phase of the research. The following list presents the evaluated concepts:

I would like to:

- Know how many people I can reach
- Know career choices of people in my network
- Find people with similar interests and hobbies
- Find people with opposite opinions and views
- Find how to reach someone through a path of friends
- Know what useful skills people in my network have
- Find where people in my network live
- Track the history of a relation between two people
- Study what clusters of friends there are
- See the strength of a bond between two people

Each participant was asked to evaluate their interest in the presented ideas and to order them accordingly. The purpose of this activity was to refine the information gathered on the most important possible uses of the visualisation tool. This information allowed to enter the design phase with a focus on user expectations.

The deck design is included in the Appendix B.

Story boarding

Storyboarding was the last exercise of the sessions. This method actively involves users in the design process and enables them to generate diverse ideas. It helps the designer to ensure that the end result meets users' needs and expectations [21].

For this activity participants were asked to select a single card from the deck that seems particularly interesting to them and then present in a form of a storyboard how they see the scenario of using the application for the selected purpose. Beforehand, an example storyboard was presented to introduce the users to the method.

Figure 4.1 *Participatory design session activities*

Participants had freedom to choose to present the general situation of a usage as well as the UI close up.

The purpose of this activity was to investigate the concept from different perspectives. First, from a service design point of view, data was gathered about possible environment and context of use. Secondly, gathered storyboards served as a basis for creating a list of desired features and interactions that should be available in the designed application.

4.2.3 Study arrangement

The study comprised 4 session including altogether 16 participants. The pilot session was attended by 3 participants, and the next 3 sessions included 5, 4 and 4 participants respectively. Participants were recruited among author's fellow students and coworkers. Their background was quite varied as study included both students and working professionals of age in range from 23 to 40. The participants' nationalities were very diverse, altogether including 10 different countries of origin.

For an optimal setup, each session included at the same time people who are friends, and people who don't know each other. All sessions were conducted in June 2016, in the participants' cities of residence - 2 sessions took place in Helsinki, another 2 in Tampere.

4.3 Summary

The research consisted of two phases reaching in total 86 users. The first phase was a global questionnaire spread by the respondents themselves. Gathered data was used

to compose the initial list of possible ways of utilizing a social network visualisation tool. The information was then verified and refined in the second phase of the research where users were directly involved in the participatory design sessions. As a result, a set of artifacts was collected to be analyzed in terms of possible layout and desired functionalities.

5. RESULTS

This chapter presents the results of the conducted research. First, it focuses on the answers of the online questionnaire and metadata gathered from it. Then, the participatory design sessions are analyzed separately for each of the three conducted activities. Summary at the end of the chapter outlines the most important findings.

5.1 Self-spreading questionnaire

5.1.1 Respondents' answers

The questionnaire was answered by 70 respondents. As some of the answers were fairly complex, responses were divided into approximately 100 affinity notes, each of them representing one separate idea. The notes were analyzed using the affinity diagram. This method allows to identify the common themes across all answers and group the data into key issues under labels of different levels of abstraction [27].

The analysis has shown that the answers to the question "What would you like to know about the network of your friends?" have 3 main common themes:

- Structure of the user's network
- Knowledge about people in the user's network
- Knowledge about relations between people in user's network

Users were interested in the numerosity of their network and its growth, emerging structures like circles and clusters and the reach that the network provides. These topics were grouped under the "structure of the network" category. Next, respondents showed interests in acquiring information about other people in their network,

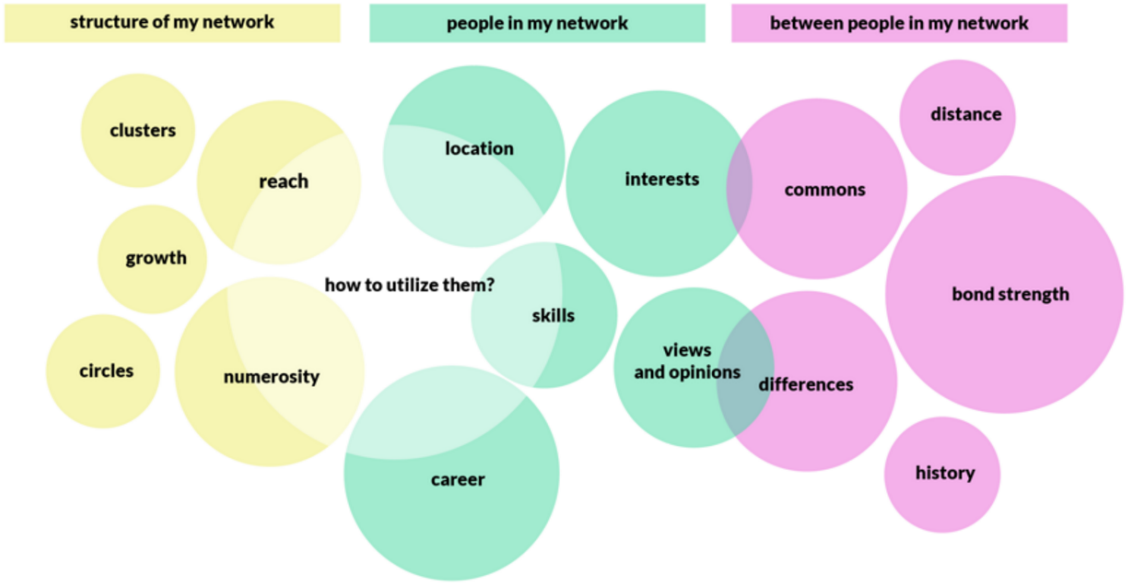


Figure 5.1 *Questionnaire results summarized*

in particular their location, career choices, possessed skills and their views on certain topics. An important finding was that a significant group of respondents expressed interest in utilizing their network size to find people with certain skills or in certain locations to find help in various matters. Lastly, a big group of answers focused around the idea of relations between two users in the network: distance between them, relationship history, strength of a bond, similarities and differences between the two.

The results are visually presented in the Figure 5.1. The size of the bubble corresponds to the number of related affinity notes and their color indicates the category they belong to. A common theme across two categories is indicated by the white bubble.

5.1.2 Metadata

The metadata gathered from respondents was equally as important as the answers themselves. As the respondents were spreading the questionnaire, the speed and reach of the process was tracked. Five initial respondents managed to reach 65 other people in total, creating chains even up to 5 participants long.

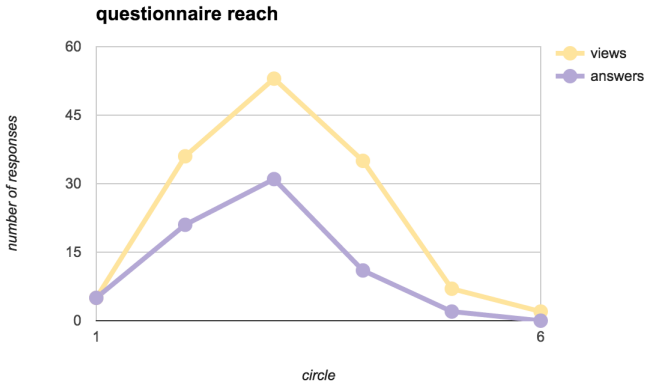


Figure 5.2 *Questionnaire reach*

The questionnaire was seen by 136 people, out of which 70 people answered, resulting in a 51% response rate. The response rate is high, what might be caused by the fact that respondents were asked directly by their friends, so they were more eager to help and answer (Fig. 5.2) [3].

The rate of the recruited friends decreased with the circle number. The further from the source, the more difficult it is to engage the respondents. Users asked directly managed to recruit on average 5 each, the second circle less than 4, gradually decreasing up to 6 circle when the chains stop and none of the people who open the link replied (Fig. 5.3).

The lifespan of the questionnaire was 11 days, with a peak of 15 replies on the first day. First circle answered and distributed the link quite fast, the next circles took more time. (Fig. 5.4). The questionnaire turned out to be distributed globally, having been viewed from 10 different countries (Fig. 5.5). This was the result of the selection of the initial participants being of different nationalities and it proved the idea of finding people in remote locations is feasible.

5.2 Participatory design

5.2.1 Background questionnaire

All of the participants who attended the sessions were asked to fill a questionnaire that allowed to gather basic information about them and their usage of social media

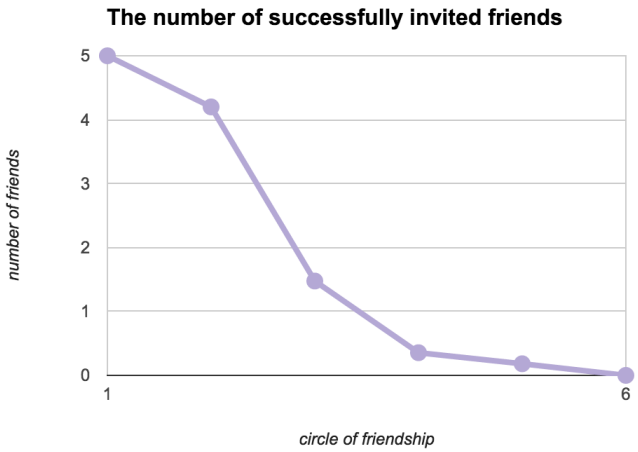


Figure 5.3 *Questionnaire spreading*

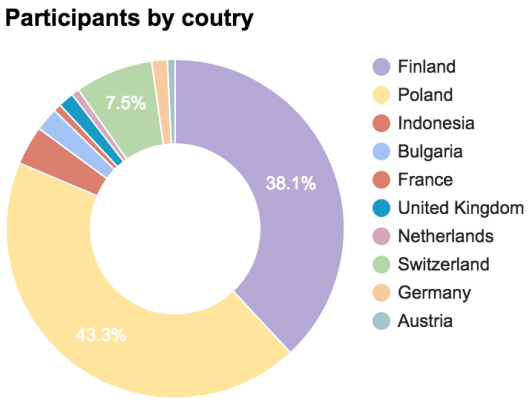


Figure 5.4 *Respondents location*

mobile apps. Altogether 16 participant attended the participatory design session: 6 female and 10 male participants, with age ranging from 23 to 40 years.

The first question of the questionnaire asked about the frequency of social media apps usage. All participant use them, majority 5 or more times per day (Fig. 5.6). Next, participants were asked about their current reasons for using a social media apps. All of them reported using social mobile apps to stay in touch with their friends, 62% use them for meeting new people and 44% explore the network of their friends (Fig 5.7).

Gathered information shows that the study was attended by a representative group

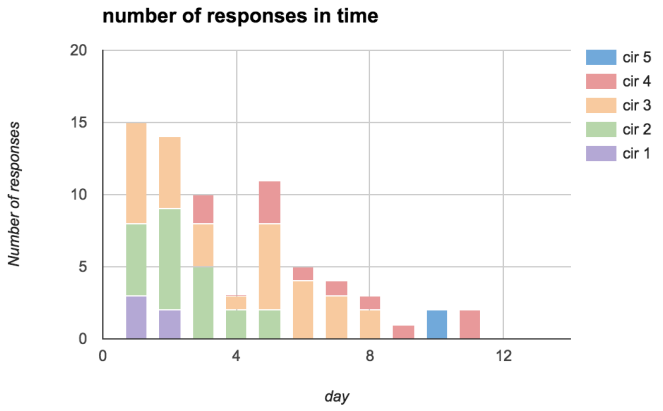


Figure 5.5 *Respondents answer time*

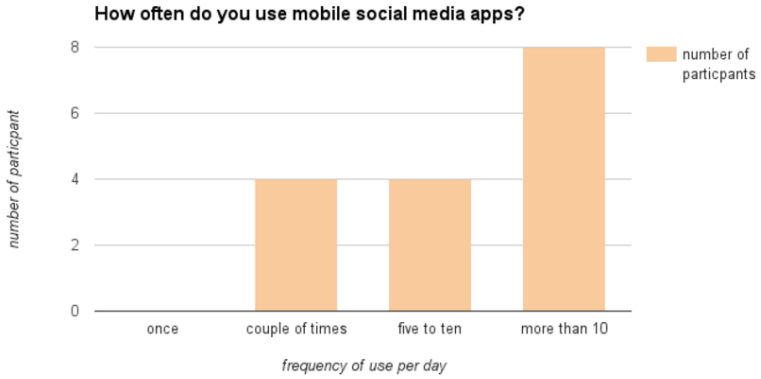


Figure 5.6 *Participants' social media usage frequency*

of potential future users. All participants were familiar with the concept of a social media mobile apps and were experienced users of those. Minority of the participants currently use social media apps for network exploration, what indicates that there might be a possible place for such an application on the market.

5.3 Body storming results

In the result of the bodystorming session 16 visualisations were gathered. The network's structure and layout were analyzed to reveal the most intuitive ways for portraying social network graphs.

The study showed that there are two main ways users think of their friendship graph. One approach shows circles of friends with the user in the middle (Fig 5.8.1), the

second one shows layers of friends with the user at the top (Fig 5.8.2). This might indicate two main mental models users have of a social network graph. Both layouts emphasise hierarchy of well known and lesser known friends.

Majority of the participants included clusters of friends in their visualisations. Some of the nodes are very close in their location, others are tightly connected with lines (Fig. 5.9). This shows how participants group their friends. The groups in the visualisations were based on geographical location or relationship type. Users created groups like family members, classmates or colleagues (Fig. 5.9).

Some participants highlighted the differences in connection strength by marking weak connections with a dashed line (Fig. 5.10.1). Others emphasised the sense of direction between the network nodes,showing the direction of a path to reach a certain person by using arrows (Fig. 5.10.2).

5.4 Card sorting results

The card sorting results allowed to identify the most popular purposes for using social network visualisation app. Participants were asked to sort 10 cards in order of preference. The cards were then assigned points (10 for the first one, 1 for the last one in order). From the gathered data mean score and standard deviation were calculated (Tab. 5.1).

Table 5.1 *Card sorting results*

Concept	**MEAN**	**SD**
Find people with similar interests and hobbies	6.7	3.0
Know what useful skills people in my network have	6.1	2.6
Find how to reach someone and see a path between us	5.2	1.6
Know career choices of people in my network	5.1	2.7
Find where people in my network live	4.9	2.5
Know how many people I can reach	4.6	2.7
See the strength of a bond between two people	3.9	3.2
Track the history of a relation between two people	3.5	3.0
Study what clusters of friends there are	3.5	2.1
Find people with opposite opinions and views	1.4	2.5

Results show that the most important use of the app would be to find other people with similar interest and useful skills. Users would also like to see a path between

them and a selected person. The standard deviations for the scores turned out to be relatively big, so the results cannot be treated as decisive. However, they show that all the mentioned purposes have users interested them.

5.5 Storyboarding results

Storyboards created in the final activity of the session allowed for creating a list of desired features (Fig. 5.11). Users were free to illustrate both the context of use and a UI closeup. The functionalities mentioned by the participants were analyzed and grouped into 3 main categories:

Information:

- Profile view presenting details about a given person
- Path view presenting a way to reach a certain person travelling node by node
- Bond view with friendship timeline (activities done together, pictures together, common places)
- Map view with ability to zoom in and out, seeing a numbers of friends in a given location
- Overall view presenting the network structure

Search:

- Search based on a proximity circle, location, distance, occupation
- Search results list sortable by all of the above

Communication:

- Direct chat
- Chat with all people who belong to a certain path
- Chain of introductions

5.6 Summary

The research phase consisted of two stages. The first one, a self-spreading questionnaire was answered by 70 respondents around the globe. It asked about the information users would like to obtain about the network of their friends. The initial group of 5 participants initiated questionnaire spreading, resulting in creating chains up to 5 respondents. The results showed that users would like to explore their network of friends to gain information about the nodes, edges and overall structure of the network graph. One of the most prevalent ideas was utilizing the size of the network to find people with certain interests or skills.

The questionnaire was followed by the second stage of the research phase - a participatory design sessions. 4 sessions were conducted, reaching altogether 16 participants. The sample was small but varied and consisted of potential users of the app. The artifacts gathered from the first activity of the session indicated that users visualise their social network with a clear hierarchy in mind. Created visualisation layouts were based mostly on a layered view or nested circles. The card-sorting activity strengthened the results from the first stage of the research - participants would like to use a social network visualisation apps to find people with common interests or a certain skills. Other purpose for using such an app would be to find a path of friend-of-a-friend to reach a certain person. The final activity of storyboarding identified the desired features of the discussed application.

The research phase reached altogether 86 users. Gathered data allowed to answer the posed research question about possible uses for a social network visualisation app. Artifacts collected during participatory design sessions were analyzed and constitute a major part of app design inspiration, described in detail in Chapter 6.

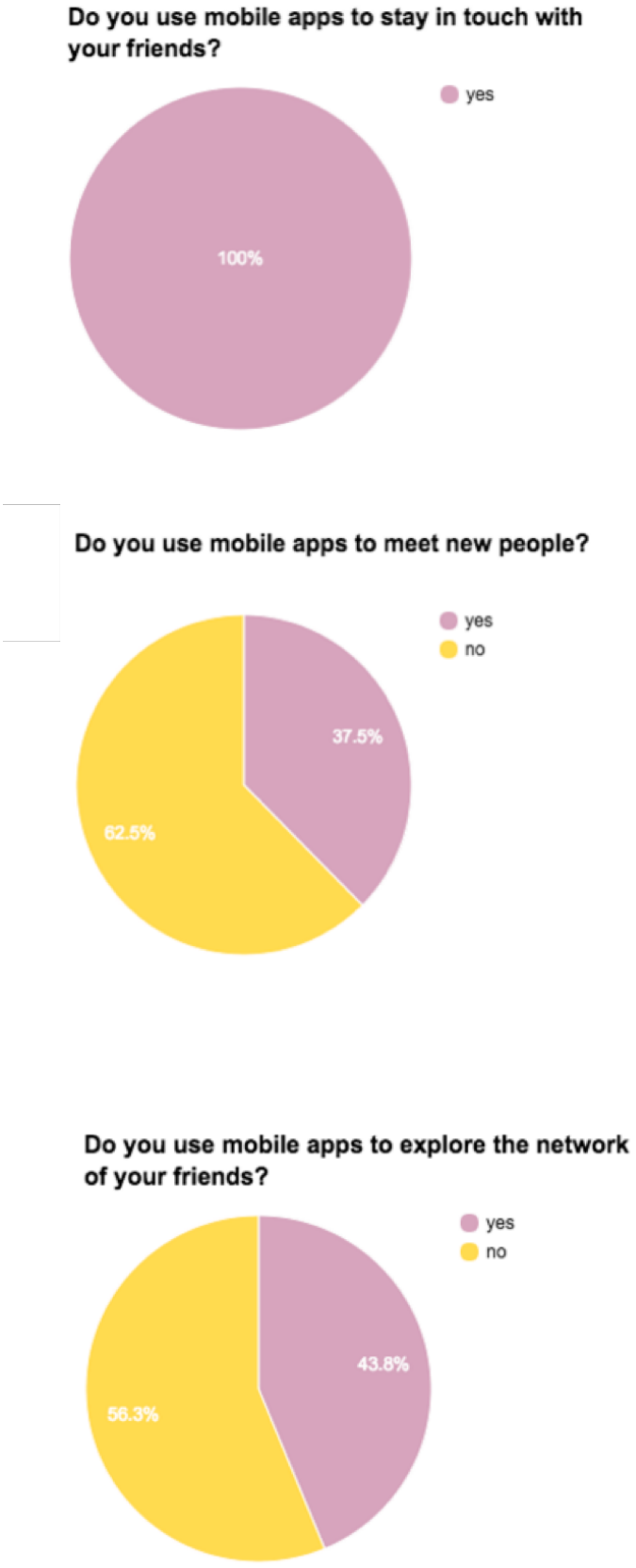


Figure 5.7 *Participants social media usage*

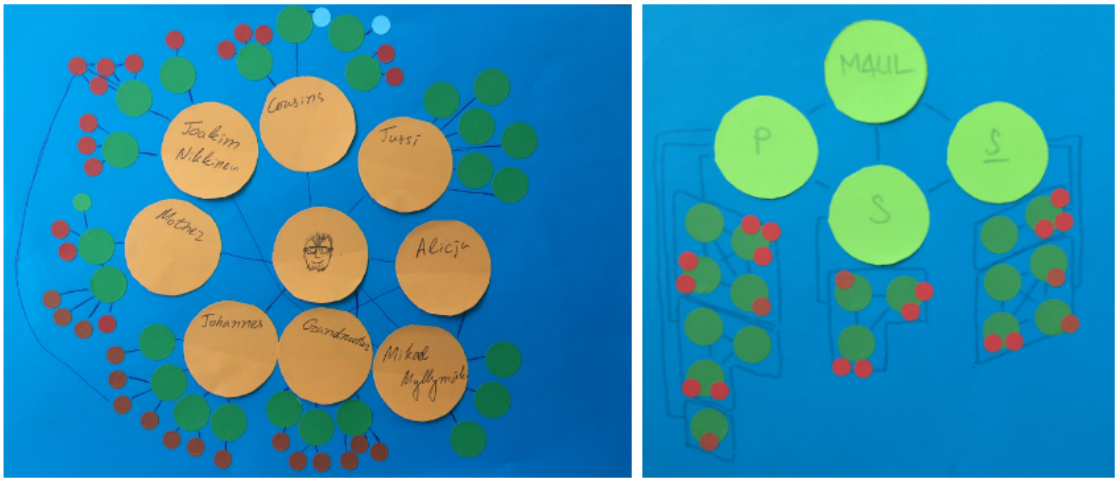


Figure 5.8 *Bodystorming artifacts - layout*

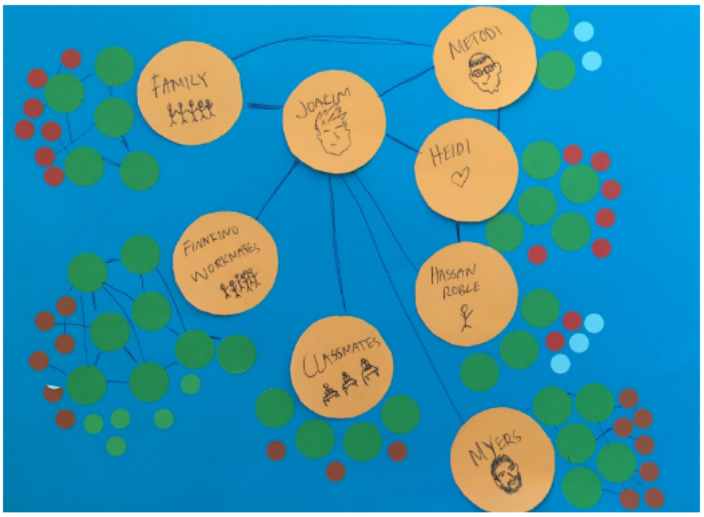


Figure 5.9 *Bodystorming artifacts - clusters*

Figure 5.10 *Bodystorming artifacts - details*

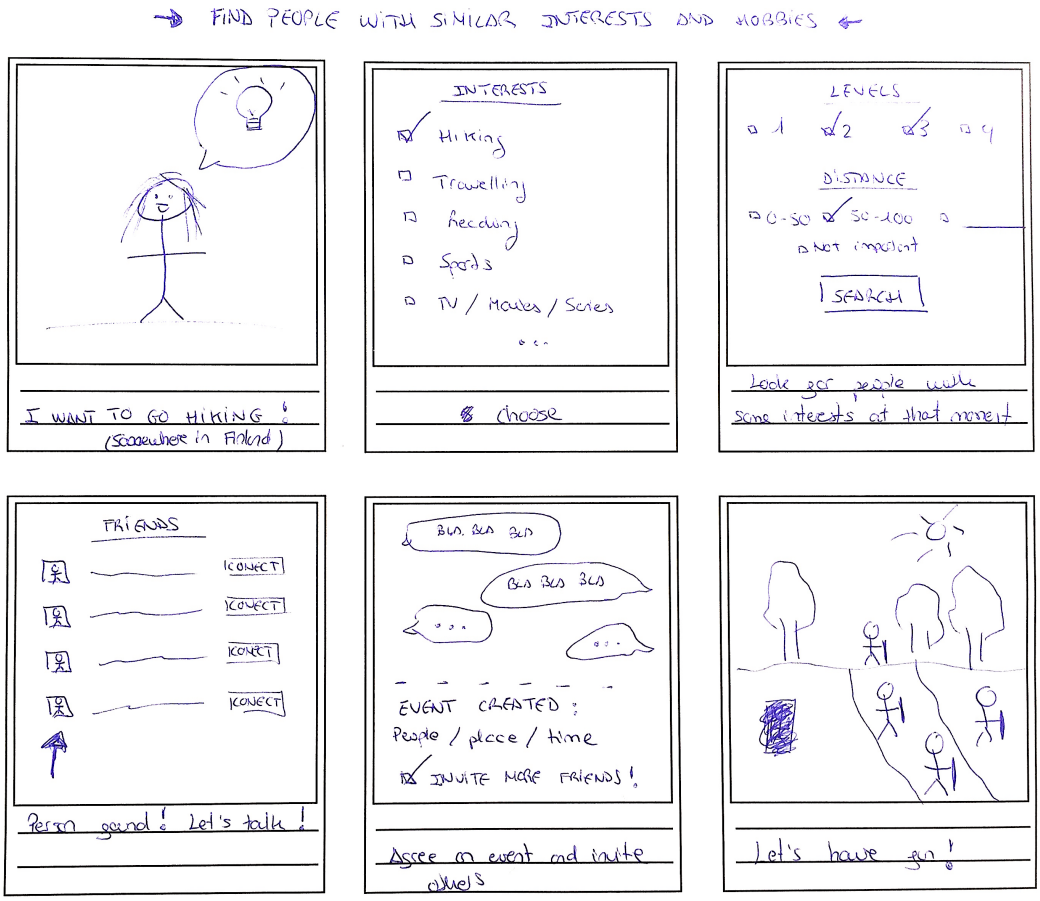


Figure 5.11 *Example of a created storyboard*

6. DESIGN

This chapter describes the designs created to depict possible social network visualisations. First, the chapter lists the goals the designs attempt to achieve. Next, it describes applied techniques for creating successful network visualisations. Finally, the designs are presented in detail and reasoning behind them is explained.

The final results of the design phase is composed of 8 short animations. Links to all of them are available in the Appendix C.

6.1 Design goals

The designs were created with a main goal of presenting possible approaches to social network visualisations on a mobile phone screen. They present information that should be made accessible to the users and interactions with data that the visualization should support. The designs are based on the results of the previously conducted research (described in chapters 4 and 5) as well as the literature recommendations.

The goal experiences the designs attempt to provide are exploration and discovery. They are selected from PLEX cards set that lists a collection of sources for enjoyable experiences [33]. With these goals in mind, created visualisations concentrate on presenting several possibilities for social network traversal and analysis that user can perform. Additionally, an emphasis is put on motion design and the way it can support the visualisation.

6.2 Design techniques

Key aspects of network visualisation were considered when creating representations of a social network graph. These include: positioning of the nodes, representation of the nodes and edges, and available interactions [10].

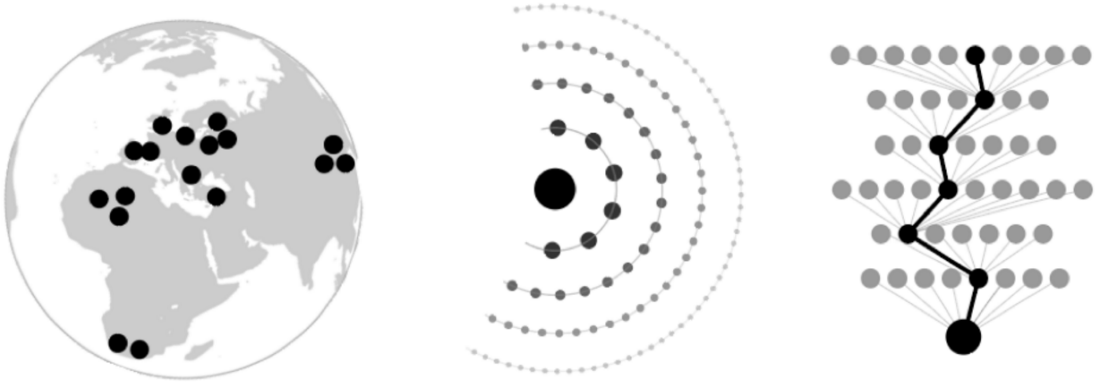


Figure 6.1 *Node positioning.*

6.2.1 Positioning of the nodes

In case of social networks, the extensive number of connected nodes makes the task of laying them out within the representation nontrivial. Depending on a chosen representation, it can emphasise different aspect of the network: geographical location (Fig 6.1.1), hierarchy of the nodes (Fig 6.1.2) or ability to travel along a path (Fig 6.1.3). These 3 basic approaches for laying out the nodes were based on the research results obtained from participatory design sessions described in detail in Chapter 5.

6.2.2 Representation of the nodes and edges

Nodes were assigned a set of preattentive visual properties, like color and size, that can be processed in a spatial memory without a conscious action [36]. The size of a node carry a meaning - it indicates the position in the hierarchy, the importance of a node in the network or a distance to it from a specified starting point. (Fig 6.2.1). Each node can be labeled with information about the individual like name, age, number of friends or a photo.

Edges are represented by straight lines or arcs connecting two nodes. They also have assigned values representing features like strength of a connection or the creation date. These are indicated by numerical labels, but also by attributes like thickness or opacity (Fig 6.2.2).

Figure 6.2 *Representation of nodes and edges.*

6.2.3 Interactions

The amount of data that might be presented to the users about their social network is impossible to be laid out at the same time on a small computer or mobile phone screen. In the presented designs, the details can be hidden from the user and made visible on demand, making the visualisation interactive. This approach provides a global overview of the collection of data and, at the same time, lets users analyze specific details or parts that they may judge as relevant to their goal.

In presented social network visualisations user can manipulate the view by zooming to a specified location in the graph, swiping to go to the next available circle of friends or taping to get detailed information on a specified node or edge. The design follows Shneiderman's rule of manipulable information representations "First overview, then zoom and filtering, finally details on demand [49]".

6.2.4 Motion

Motion in User Interface design has many pragmatic applications. For instance, it helps to direct user's attention to the new elements on the screen or to elements that change their location or other properties. What is more, motion aids storytelling and adds new information to the visualisation. It can depict a chronological order to show the overall process of the network growing over time or it can emphasise user's connection range by animating edge by edge from one point through all attainable nodes. All the animations included in the design are linked in the Appendix C.

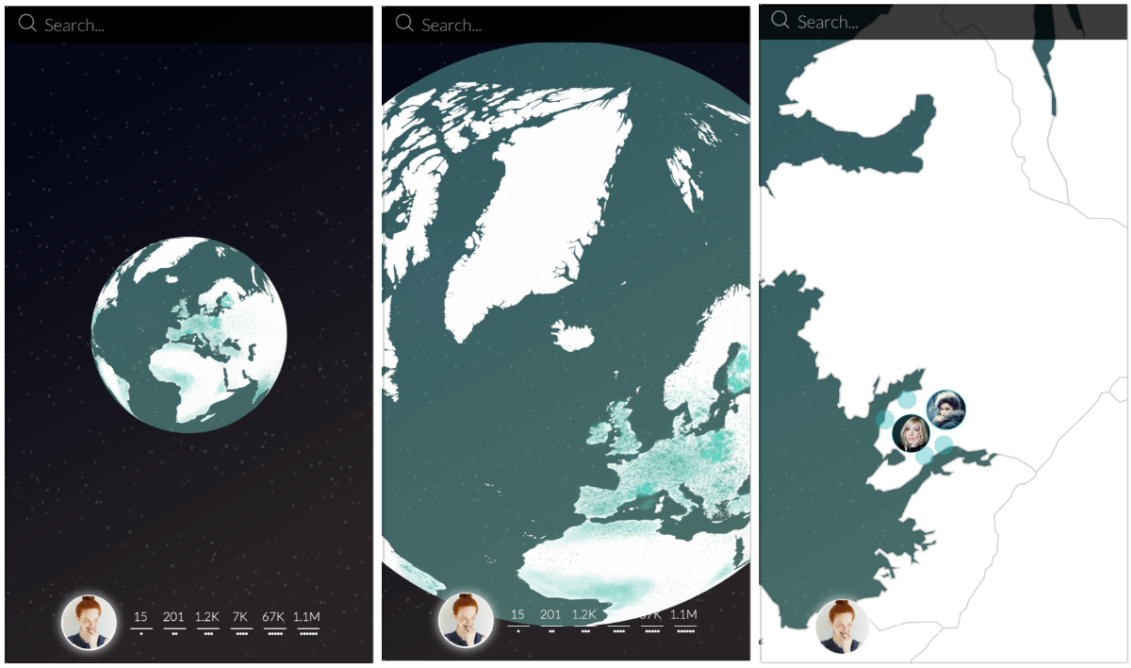


Figure 6.3 *Map-based approach for graph traversal.*

6.3 Graph traversal design

Created visualisations present different approaches for social network traversal. Three distinct concepts are proposed: geographical, layered and circle-based. All of them are based on ideas drawn from the participatory design sessions.

6.3.1 Geographical approach

Based on users' inquiry to search for friends in specified locations, the first design is based on a map view. All the nodes of the user's social network are marked on a map, indicating places with bigger and smaller density of accessible friends and friends-of-friends. Different zoom levels reveal different amount of details about the nodes like photo or name (Fig. 6.3).

Interactions:

– Zoom in and zoom out - User can change the zoom level by a zoom gestures to see an overview or a closeup of a certain area

- Pan - User can freely move the view
- Tap - User can tap on a selected node to see more information about a given user, an option to examine the path or to chat.

Networks arranged on a map to represent the geographic distribution of a population were drawn already by the precursors in a social network visualisation field [16]. Moreno illustrated football players on a field [41], Leonard and Loomis showed befriended families on a map of households [31]. Similarly, Festinger and Back drew network connections on a map of residence locations [14]. On a global scale this literal approach would not be possible. A heatmap is a more practical solution that indicates density of network nodes. Leskovec and Horvitz visualised in that way the global distribution of Messenger users, mapping number of users with color intensity and placing the information on a map [32]. The geographical approach to social network visualisation presented in the thesis is a fusion of those two views. It allows user to see the overview of his network globally and to zoom in to increase the amount of details with every zoom level.

6.3.2 Layer-based approach

Layered approach emphasises the ability to travel along a path through the graph. First, user's first-circle friends are presented (Fig. 6.4.1). When user selects a certain person by tapping, the view changes: first-degree friends form a first layer at the bottom of the screen and selected person's friends are now presented (Fig. 6.4.2). This procedure can be repeated to allow user to explore the graph and discover interesting personas in his social network. Layers get stacked at the bottom of the screen so user can easily see the history of his choices.At any time user can tap and hold to see detailed view about the selected person. (Fig. 6.4.3).

Interactions:

- Tap - By tapping on a person user changes his location in the graph, and changes the point of view to see selected person first-degree contacts.
- Tap and hold - Tap for details - User can tap on a selected node to see more information about a given user, an option to examine the path or to chat.
- Swipe up and down - User can switch between created layers, go back in the history of his selections.

Figure 6.4 *Layer-based approach for graph traversal.*

Layered graph drawing is a relatively common technique used for hierarchical networks visualisation [7]. It is known as Sugiyama-style graph drawing after Kozo Sugiyama who first created an algorithm for aligning graph nodes in horizontal layers [52]. The layered approach to social network visualisation presented in the thesis is a modification of a classing layered graph. User can see only one level at a time and layers are created dynamically based on user's location in a graph. At a time, user sees only the closest nodes that he can be directly reached from his current position. The presented visualisation was inspired by a depth first graph traversal technique.

6.3.3 Circle-based approach

The third approach is based on the six-degrees of separation phenomenon. User's node is placed the middle of concentric circles representing each of six circles of separation. An active circle that the user is currently browsing through, is indicated by enlarged nodes containing users' pictures.

Interactions:

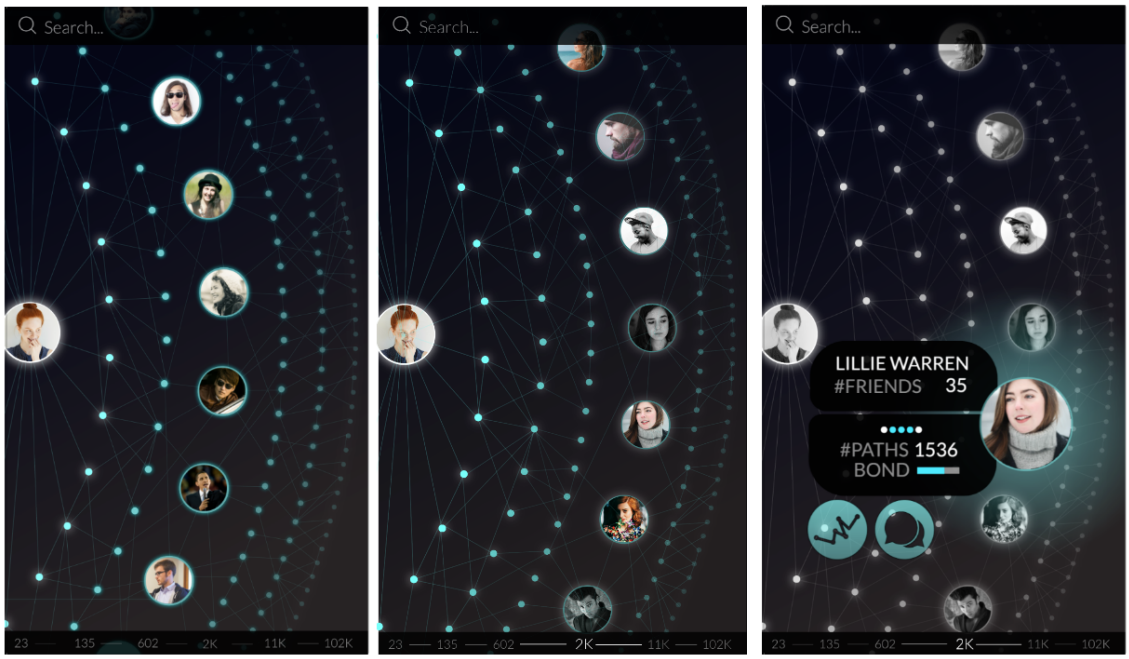


Figure 6.5 *Circle-based approach for graph traversal.*

- Swipe left/right - By swiping left user changes the active circle to a circle of a smaller degree of separation. Swiping right changes the active circle to a circle of a higher degree.
- Swipe up down - User can see more friends from a given circle by swiping up or down as he would rotate the circle.
- Tap for details - User can tap on a selected node to see more information about a given user, an option to examine the path or to chat.

Circular layout is a network visualisation style in which the nodes of a graph are evenly placed on a circle. This layout is also referred to as a chord diagram [8]. It is often used as an aesthetically pleasing way of visualising inter-relations between data in a graph [26]. For example, it has been utilized by Yee et al. for graphical representation of a Gnutella file-sharing network [58]. The circle-based approach to social network visualisation presented in the thesis is inspired by the classic chord layout. However, it was adapted to portray the six degrees of separation phenomenon. Users were divided into six circles drawn concentrically to intuitively portray path distances from the user.

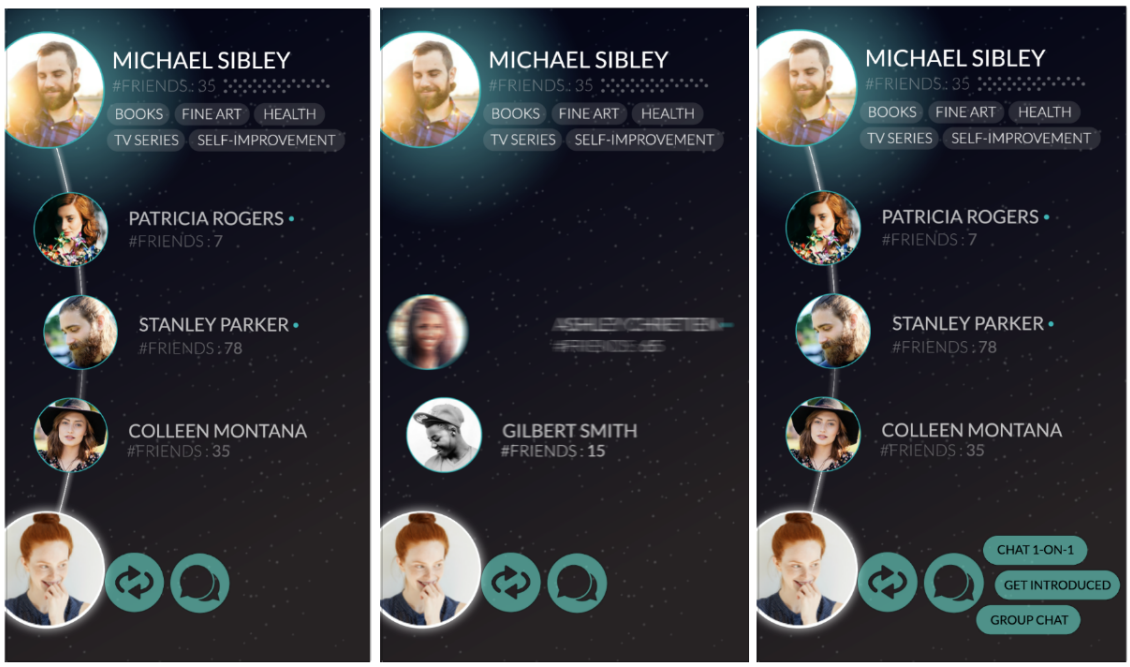


Figure 6.6 *A view showing a path view between two users.*

6.4 Path view

Another important aspect of small-world network social media visualisations taken into consideration is the design of a path view presenting a chain of friends allowing to reach a certain person in the network. The visualisation from Fig. 6.6 shows how to reach a person form a fourth circle by contacting a friend and two friends-of-a-friend. If there is more than one possible path, user sees an option to refresh the view and load the other option (Fig 6.6.2). There are 3 options of chat available: personal chat, group chat and introduction request (Fig 6.6.3). These options are based on results of the conducted research showing demand for diverse forms of communication.

6.5 Summary

The design phase results present three alternative approaches to social graph traversal. The first one is based on a map view and focuses on showing the physical location of the nodes. In the second approach user starts with a view of his closest friends, and by selecting one of them, switches to the point of view of the chosen node. From

that he can continue travelling through the graph, seeing a selection of connections from a given node. The last approach shows nodes grouped into 6 circles, based on the degree of separation.

All of the visualisation approaches were based on the results of the conducted studies and artifacts collected during the research phase. Visualisation designs were inspired by the six degrees of separation phenomenon. It was illustrated by introducing a clear hierarchy of nodes, marked by their visual properties like size and opacity. To emphasize grouping of all users who belong to the same degree of separation different Gestalt Principles were taken into use [6]. In the case of the map-based view grouping is shown by similarity, in the layer-based one groups are designated by proximity, finally the circle-based views are based on principles of closure and continuity. The path view demonstrates the shortest way to reach a selected person, emphasising the small-world property of social networks. The designs aim to allow users to explore this phenomenon and utilize the access to visualisation to reach their goals.

Significant part of the design work was focused on motion design. As the visualisations are interactive, motions helps to guide users through the transitions by showing how the location and properties of a node change. This is especially important in the social network visualisation case, as it helps to process the vast amount of available information.

The final outcome of a thesis demonstrates an answer to the addressed research questions and presents several possible ways of appropriate presentation for a social network graph. Presented solutions are complementary and can be used together to provide users with freedom to choose the visualisation approach the most suitable for achieving their goals.

7. DISCUSSION

This chapter discusses the main outcomes of the thesis and presents answers to the posed research questions. First, it lists the possible uses for social network visualisation. Second, it reviews possible approaches to visualise a graph of user's social network. At the end of the chapter utilized research methods and design techniques are assessed.

7.1 Purposes for using social network visualisations

The possible purposes for using a social network visualisation app were investigated throughout the research phase. First, the conducted questionnaire gave a list of ideas grouped into 3 sets:

- Network structure
- Data about the people in the network
- Relationships between the people in the network

From that 10 distinct ideas were selected and evaluated in the second phase of the research. Users prioritized the given concepts, identifying top purposes for using a social network visualisation app:

- Finding people with similar interests and hobbies
- Knowing what useful skills people in the network have
- Finding how to reach someone through a path of friends
- Knowing career choices of people in the network
- Finding where people in the network live
- Knowing how many people can be reached

Some of the evaluated ideas turned out to be less popular. Users did not prioritize concepts of tracking the history of a relation, studying friendship clusters, or finding people with opposite opinions and views. The results show that in this particular case users were interested mostly in basic statistics about their network and ability to browse for people who share their interest or can help them in some way.

7.2 Visualisation approaches

Research phase identified 3 possible approaches for successful social network graph visualisation that were then developed during the design phase. The visualisations were based on:

- Geographical approach showing the nodes' physical location
- Layer-based approach allowing to explore the graph by traversing it one node at a time
- Circle-based approach that emphasise the grouping of the network nodes by the degrees of separation

Created visualisations present detailed information about user's social network. In particular, they shows basic data about the graphs structure - like total reach and number of friends per circle, data about graphs nodes - like picture, name, interests and meta-data - degree, number of friends and data about network edge like strength factor or creation date.

Except for the graph traversal functionality, other user needs were identified. One of the highly requested features was advanced search and filtering option that takes into account separation degree, interests and location. Another important part of the application would be the ability to communicate with other users either through a group or personal chat. What was especially prominent, many users expressed interest in seeing a detailed path view, showing details on possible ways of approaching a selected person. This finding emphasises users' understanding of a small-world phenomenon and shows their interests in utilizing it.

7.3 Methodological Reflections

Methods utilized during the thesis project were based on a selection of traditional techniques like questionnaire, storyboarding and card-sorting. However, they were adjusted to fit the needs of this particular research.

The initial questionnaire study was a novel approach, as one if it main goals was to measure the pattern of spreading it by respondents themselves. However, the number of reached participants was limited, what could somehow reduce the reliability of the result. The study could be repeated with a different set of initial respondents to confirm if the measurements would be consistent and prove itself reliable.

The feedback gathered from the participants during the participatory design session was adequate to create valid conclusions about the evaluated concept. The study sessions included three diverse activities based of telling, making and enacting. Analysis of the results could have been simplified if the session were designed to produce more quantitative results. Sessions could have been more successful if they were observed and recorded by another facilitator, who would have fully focused on documentation of the conducted activities.

Altogether, the methods used to gather data about the participants behavior and opinions provided adequate information that made the establishing valid conclusions possible. They allowed to answer the research questions with satisfactory certainty, as they gave several suggestions for possible approaches for successful social network visualisation and identified some of the most probable ways of utilizing such a tool. All the findings were later utilized in the design phase of the thesis project.

7.4 Design Reflections

A research phase concluded with an extensive list of concepts that should be covered in the social network visualisation application design. From all the gathered ideas, there was a need to select a smaller subset of them to focus on during the design phase. The chosen approach was to visualise different ways of social network graph traversal along with a path view showing a chain of friends allowing to connect two people in the graph. Created designs can be used separately or together as alternative ways of visualising the same information.

Created visualisations do not cover the whole application design. As they focus on

presenting selected aspects of it, more screens would be necessary to make it become a fully functional app design. In particular, the details of a chat, search and search result should be illustrated.

Designs were not evaluated. User test should be conducted to access their appropriateness and suitability. As they present alternative ways of visualising the same information, they could be compared with each other. Additionally, a possible uses for this kind of an application could be mapped to the most suitable visualisations.

8. CONCLUSIONS

This chapter concludes the results of the thesis project by assessing its importance and relevance. The results are compared to previous research in the social network visualisation field. At the end of the chapter the future work recommendations and suggestions for further research are given.

8.1 Success and importance of the research

The previous studies that have been conducted to discover useful method for small-world network visualisation focus on complex concepts like clusterization [56] or semantic zooming [28]. It can be noted that researchers' work concentrates on creating visualisations that can be useful in the study of social networks conducted by scientist. The solution provided by the thesis however, focuses on end users who do not have any extensive technical knowledge in the area or any professional training. Additionally, in comparison to previously conducted research, the designs were curated to work on a mobile phone screen.

Overall, the research and design can be considered successful in exploring possible ways to visualise a social network graph. The final concept consists of elements that can be effective solutions for visualising structure of a social network taking into account small-world and six-degrees-of-separation phenomena. Additionally, the research identifies several possible purposes of utilizing social network graph visualisation. Regarding the concept itself, it was acknowledged as engaging and encouraging. According to the study participants, they would see themselves exploring their network graph if such a tool existed.

8.2 Future work

The project timeframe did not allow to research the concept of social network visualisation to the full extent. The process could be benefited from further iterations

consisting of research, design and evaluation phases.

Set of created designs can be extended to cover functionalities like search and chat. From the designed screens a fully interactive prototype could be created to be tested by users. Evaluation sessions should be arranged to assess the designs and identify potential usability problems, recognize users' preference in terms of appearance, as well as to evaluate the speed and accuracy for obtaining information from the provided visualisations.

Furthermore, the aspect of a source of the feed of friends should be carefully considered. Research in this area should identify the most appropriate way for adding friends through the application. Approaches that can be considered are: importing the feed from the existing social media accounts or connecting users by automatic proximity detection technologies like Bluetooth, NFC or WiFi-Direct. Finally, the visualization tool can be developed as a mobile application and made available for multiple platforms.

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APPENDIX A. QUESTIONNAIRE DESIGN

APPENDIX B. CARDS USED IN CARD-SORTING ACTIVITY

KNOW HOW MANY PEOPLE I CAN REACH

KNOW CAREER CHOICES OF PEOPLE IN MY NETWORK

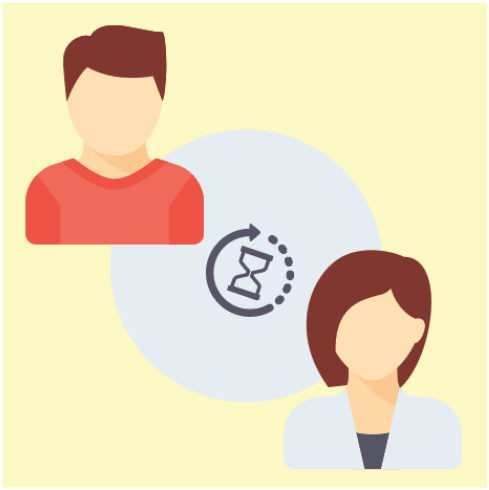
FIND PEOPLE WITH SIMILAR INTERESTS AND HOBBIES

FIND PEOPLE WITH OPPOSITE OPINIONS AND VIEWS

FIND HOW TO REACH SOMEONE, SEE A PATH BETWEEN TWO PEOPLE

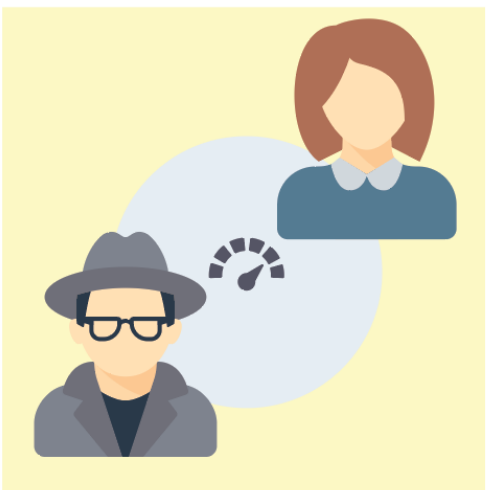
KNOW WHAT USEFUL SKILLS THEY HAVE

FIND WHERE PEOPLE IN MY NETWORK LIVE



TRACK THE HISTORY OF A RELATION BETWEEN TWO PEOPLE

WHAT CLUSTERS OF FRIENDS THERE ARE



SEE THE STRENGTH OF A BOND BETWEEN TWO PEOPLE

APPENDIX C. DESIGNED ANIMATIONS

Circle-based approach:

- https://youtu.be/Ao7PyhU4A_Q
- https://youtu.be/TzPQzZmE33E
- https://youtu.be/ZXch4yVaQzc

Layer-based approach:

- https://youtu.be/-dGlTzdj7Gg
- https://youtu.be/X0pF6c8hkEY
- https://youtu.be/PlTpP7d1lx0

Map-based approach:

- https://youtu.be/24li34VmMLM
- https://youtu.be/UbazUR02IvI

Path view:

- https://youtu.be/_2GQgzOce60